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EXPERIENCE WITH PARTICLE BACKGROUNDS AT LEP

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Paper presented at the Fourth European Particle Accelerator Conference (EPAC '94),
London, United Kingdom, 27.6.-1.7.1994

Geneva, Switzerland
27th June 1994

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Experience with Particle Backgrounds at LEP

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Abstract

To protect the experimental detectors from the potentially very high electron and photon background rates in an e^{\pm} collider a complex collimator system has been designed and included into the LEP layout. The main features of the protection collimator system are described and operational experience gained in optimising background levels at 45 GeV beam energy is reported. Background rates at the LEP detectors can be kept below acceptable levels, allowing for stable detector operation, precise luminosity measurements, and clean event analysis for Z^0 physics.

1. BACKGROUND SOURCES

Beam induced particle background rates at 45 GeV beam energy are orders of magnitude higher than can be tolerated by the LEP detectors. Synchrotron radiation (SR) photons radiated in dipole and quadrupole fields can reach the detectors directly or after scattering from vacuum equipment around the interaction point (IP). Off-energy beam particles created by beam-gas bremsstrahlung or scattering with thermal photons reach the detectors after being over focused in the strong low-beta quadrupoles. The energy spectrum of the two background types is very different. Photons which come directly from SR in quadrupoles (direct photons) and those which are scattered before arrival (forward scattered photons) have average energies of about 80 KeV. Photons which are back scattered from obstacles downstream of the detector (back scattered photons) have lower energies, $\langle E \rangle = 50$ KeV, due to the inelastic Compton scattering process. Off-energy electrons fill a broad spectrum centered around 50% of the beam energy. While off-energy particles and direct and forward scattered photons arrive in time with the beams, back scattered photons arrive at the detectors with a delay between 50 ns and 500 ns, depending on the distance to the back scattering object.

SR photon and off-energy background sources in LEP have been extensively studied using Monte Carlo methods [1], in order to specify a collimator protection system to be included in the LEP design.

Off-energy particles can be simulated with great accuracy, but they are difficult to collimate as these particles stay close to the beam until the last strong quadrupoles, which bend them into the experiment. The amount of background from beam-gas bremsstrahlung is proportional to the gas pressure along the straight sections and the last bending cells

around the IP's, but is independent of beam energy. The yield of high energy photons and off-momentum particles from scattering with thermal photons rises quickly with beam energy, but is still small at 45 GeV [2].

Simulation of SR background is much more complicated and consequently less accurate. On the other hand, photons can be collimated more easily. In LEP, without collimation, the experiments would be hit by approximately 10^{13} photons per sec and per mA of beam current; seven orders of magnitude above tolerable levels.

2. PROTECTION STRATEGY

The LEP collimator protection system consists of 72 collimators. Eight horizontal and eight vertical collimators are installed symmetrically around each of the four interaction points. Eight aperture limiting collimators are placed in the arc or around IP5 (Table 1). Each collimator consists of one or two tungsten jaws of about 30 radiation lengths, with adjustable openings [3]. 'Z' collimators protect electrostatic separator plates from SR photons, while the horizontal collimators near quadrupoles QS17 and QS23 protect the LEP luminosity detectors, inside COLH.QS1's, from off-energy particles created in the arcs.

Table 1
LEP collimators (h=horizontal, v=vertical plane)

collimator name	distance from IP (\pm m)	type of collimator	nominal opening (45 GeV)
COLH.QS1	8.5	SR (near) h	$\pm 15\sigma$
COLV.QS1	8.7	SR (near) v	$\pm 30\sigma$
COLZ.QS2	21.3	ZL v	± 35 mm
COLZ.QS4	66.1	ZL v	± 35 mm
COLV.QS5	98.	SR (far) v	$\pm 25\sigma$
COLH.QS6	121	SR (far) h	$\pm 14\sigma$
COLH.QS17	420	off-E, h	-12σ
COLH.QS23	640	off-E, h	-12σ
COLH.IP5	IP5	aperture, h	$\pm 10\sigma$
COLH.QL13L&R	IP5	aperture, h	$\pm 11\sigma$
COLV.QD30	arc	aperture, v	$\pm 20\sigma$
COLH.QD20&40	arc	aperture, v	$\pm 22\sigma$
COLH.QF31&33	arc	dispersion	$\pm 10\sigma$

The 'far' collimators prevent the strong photon fans from dipole radiation from reaching the interaction area. They ensure, in combination with the 'near' SR

collimators, that photons from the arc cannot reach the detectors unless they are Compton scattered at least twice. The far SR collimators also reduce the number of photons radiated from distant quadrupoles that impinge on the jaws of near SR collimators and are scattered into the detectors. The 'near' SR collimators protect the experiments from scattered photons, but become increasingly scattering sources themselves, with reduced openings. The near collimators also intercept off-momentum particles before they can reach the detectors.

Aperture limiting collimators, placed far from any experiment, are required in order to ensure that SR collimators, in direct view to the IP's, do not intercept beam halo particles. Detailed shower calculations have shown that a single aperture collimator per plane is not efficient enough. Therefore secondary collimators, one per beam, have been added [4].

3. LEP DETECTORS

The detectors at the four experiments at LEP combine several types of tracking devices as well as calorimeters to measure the total deposited energy of electrons, photons and hadrons.

The calorimeters are not sensitive to low energy SR photons but those used to measure the Bhabha cross section are quite sensitive to off-momentum electrons.

The tracking devices used in the experiments include silicon vertex detectors and gas detectors like drift chambers and time-projection chambers. Silicon vertex detectors are situated just outside the beam vacuum chamber. Although they can be damaged by large radiation deposition, their radiation hardness is adequate for the expected doses under normal collimator conditions. As for the gas detectors, while the energy deposition due to a SR photon may be comparable to that expected for a minimum ionizing particle, the spatial resolution is so good that there is no adverse effect on pattern recognition for photon fluxes of the magnitude achieved. The limitation on the operation of gas detectors is the average current drawn on the sense wires. Deposits may form on the wires and in extreme cases wires may become insensitive or may break. Under severe background conditions during times of unstable beams or when collimators are retracted beyond their nominal position, the current drawn is so large that the chamber cannot be operated at the normal voltage. At lower voltage the efficiency for detecting tracks drops and the quality of particle type identification is substantially reduced.

Calorimeters and gas tracking detectors in the LEP experiments have been used for background measurements. They provide rates, energy and spatial distributions of off-energy electron and SR photon interactions within the detectors. The detection efficiencies of these detectors for beam induced

background particles have been evaluated with Monte Carlo methods, allowing a comparison of measured rates with background predictions.

A very important source of information about the origin of the SR photons is their arrival time relative to that of the beams at the IP. The drift chambers and time projection chambers (TPC) in the LEP experiments are well equipped to measure the photon arrival time. The time resolution is good enough in some cases to distinguish photons back scattered from the 8.5 m collimator (the delay in this case is about 50 ns) from the forward photons and identification of photons scattered from as far away as 80 meters is possible [5]. Various back scattering sources in the beam line including collimators, separator plates, and a beam-pipe transition at about 55 m have been clearly identified from the photon time distributions and the rates are consistent with expectations.

4. OBSERVATIONS

The collimator protection system has been used since the start of LEP and has proven its necessity and excellent performance [6]. In fact many LEP detectors cannot be turned on with colliding beams in LEP until collimators are set to their nominal openings of Table 1. Furthermore, the experiments must also be protected by collimators during the ramp and squeeze phase against high radiation doses from direct SR photons.

4.1 Aperture limits

Aperture limiting collimators located far from the experimental insertions are needed in both transverse planes. Detector backgrounds increase when aperture

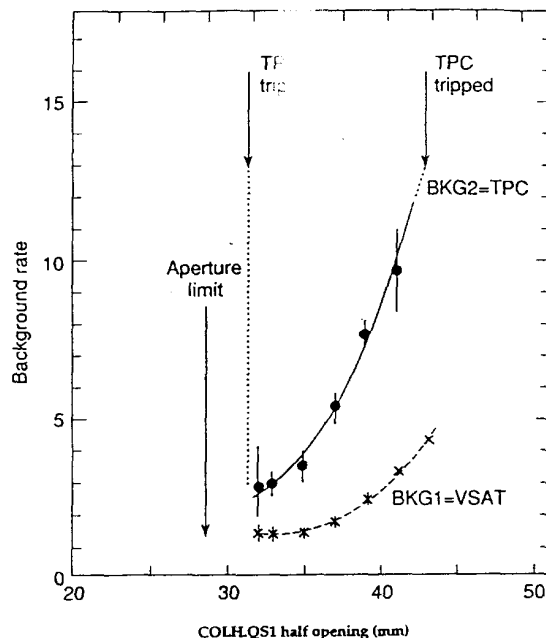


Figure 1: Scan of the near horizontal collimators COLH.QS1 around DELPHI

limiters are opened, even for stable beam conditions, and rise very sharply if SR collimators are set close to or within the tightest aperture defined by the aperture collimators (see Fig.1 and 2). A safety margin of $2\sigma_x$ and $5\sigma_y$ in the horizontal and vertical plane respectively has proven to be necessary in order to avoid the scraping of halo particles on collimators around the IP's.

4.2 Off-momentum background

Off-momentum background in LEP has generally not been a problem. Rates are small (few 100 Hz single rate) and agree well with predictions. Occasionally spikes of high energy particles are observed in the detectors when beams are unstable, mainly at the beginning of fills, or when large orbit deviations occur. This effect is enhanced when SR collimators have to be closed more tightly in order to reduce high photon backgrounds.

4.3 Synchrotron radiation background

This is the most difficult background to control. A series of measurements of background rates in the gas tracking detectors as a function of the SR collimator positions have shown a behavior in agreement with simulations. In some of the detectors both hits rates and total current are available as indicators of the photon flux. Since the various gas detectors in the four LEP experiments have different active volumes, radii, and energy response, individual simulations are required to obtain the detection efficiency and a quantitative picture of the absolute rates; however the general behavior is evident.

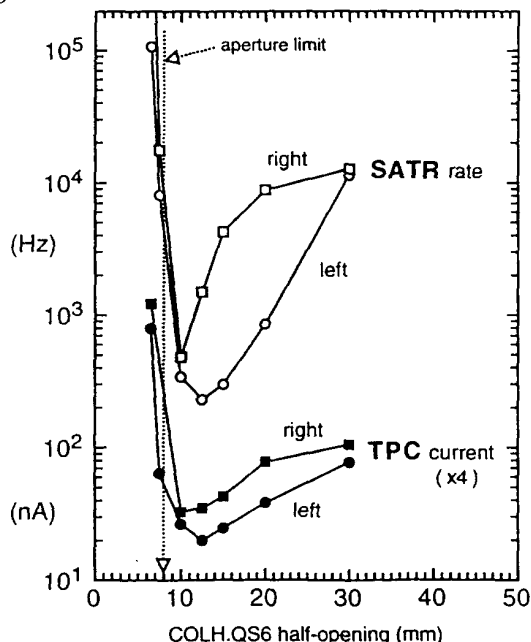


Figure 2: Scan of far horizontal collimator COLH.QS6 upstream of ALEPH.

Rates in the DELPHI TPC are shown in Fig. 1 as a function of the half-opening of the horizontal collimator at 8.5 m (COLH.QS1). As the collimator is opened from the nominal setting (35 mm) there is a steep rise in the number of detected forward-going photons. Closing the collimator by only a small amount causes it to become a secondary source of photons and electron showers and the consequent sudden rise in the background results in a detector trip.

Similar photon background measurements in the ALEPH TPC and in a robust small angle tracking chamber (SATR) are shown in Fig. 2. Here the horizontal collimator opening at 121 m (COLH.QS6) is varied. An increase of three orders of magnitude is observed as the collimator jaws move inward. Opening the collimator lets through distant quadrupole radiation which is scattered into the detectors. These data were taken with a single 45 GeV positron beam of 1 mA. In the figure "right" and "left" refer to the downstream and upstream sides of the detector, respectively.

5. CONCLUSION

An elaborate and interdependent set of collimators has been designed and installed at LEP to protect the experiments against very high rates of off-momentum electrons and synchrotron radiation photons. The collimator system has permitted the very sensitive gas detectors to operate reliably since 1989 under increasingly intense beams with excellent tracking performance. The behaviour of the collimator system has been studied in detail and has been optimised using the position, energy, and time sensitivity of the detectors themselves. Good agreement has been found between observations and simulation of the background photons and electrons.

6. REFERENCES

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